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§4. Activation Analysis for Li/V-alloy and Flibe/V-alloy Blanket Systems with and without Solid Beryllium Neutron Multiplier

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In the design activity of the FFHR2 helical power reactor, Li/V-alloy and Flibe/V-alloy blanket systems have been studied as alternatives for high efficiency operations at high temperature of up to ~700 °C. In our previous neutronics investigations, both of the blanket systems could achieve tritium self-sufficiency and adequate neutron shielding for the superconducting magnet system. For the Li and Flibe cooled blanket systems, introduction of additional solid beryllium, which multiply neutrons through the (n,2n) reaction, would be effective for enhancing the tritium breeding performance and reducing the total blanket thickness. Figure 1 shows the radial configurations of the Li/V-alloy and Flibe/V-alloy blanket systems with additional solid beryllium multiplier named Li/Be/V-alloy and Flibe/Be/V-alloy. By introducing the beryllium multiplier, low energy neutron component is increased in the tritium breeding regions as the neutron spectra shown in Fig. 2. Impacts of the changes in the neutron spectra on activation properties of the blanket systems were investigated by using the FISPACT-2001 activation calculation system.[1)]

Figure 3 shows decay curves of radioactivities (dose rates) of a V-alloy (pure V-4Cr-4Ti) structural material in the Li/V-alloy and Li/Be/V-alloy blanket systems. An operation of 30 years with 1.5 MW/m^2 neutron wall loading and neutron spectra at the position of 19.5 cm from the first wall were assumed in the calculations. It is considered that dominant radioactive nuclides in V-alloy are produced through (n,p) and (n,α) reactions of V and Ti. Since the reactions are induced only by high energy neutrons, introduction of solid beryllium multiplier, which attenuates a high energy neutron flux, reduced the dose rates of V-alloy in the Li/Be/V-alloy blanket system. For the Li cooled blanket systems, electrical insulating ceramic coating would be required on the surfaces of the V-alloy structures for suppression of MHD pressure drop of Li coolant flowing through a magnet field. Activation property of V-alloy coated with thin Er_2O_3 insulating layer, which is an attractive candidate coating material at present, was calculated by assuming a V-alloy plate of 5 mm and Er_2O_3 layer of 10 µm in thickness. For V-alloy with Er_2O_3 coating, a dose rate from Er_2O_3 was dominant after cooling of several years. The dominant nuclide in Er_2O_3 is ^{166m}Ho with the half life of ~1200 years and produced through the (n,γ) reaction with low energy neutrons. Increase of low energy neutron component by introduction of solid beryllium multiplier induced a twice larger magnitude of the activation in the Li/Be/V-alloy blanket system compared with that in the Li/V-alloy blanket system.

Radioactivities of the V-alloy structural material and Flibe coolant in Flibe cooled blanket systems with and without a solid beryllium multiplier were also analyzed by similar calculations. A low energy neutron component in the Flibe/Be/V-alloy blanket system is also increased by introduction of solid beryllium multiplier as shown in Fig. 2. However, the dominant radioactive nuclides in the V-alloy and Flibe coolant are produced by reactions with high energy neutrons. Magnitudes of radioactivities of the materials were almost comparable to those in Flibe/V-alloy using no solid beryllium multiplier.[1)]

1) Z. Li *et al.*, Plasma and Fusion research, Vol. 2, 046 (2007) pp. 1-4.

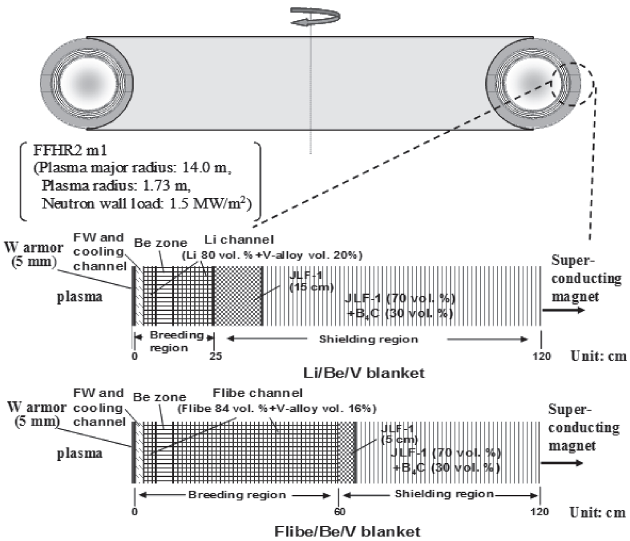

Fig. 1. Radial configurations of Li/Be/V-alloy and Flibe/Be/V-alloy blanket systems.

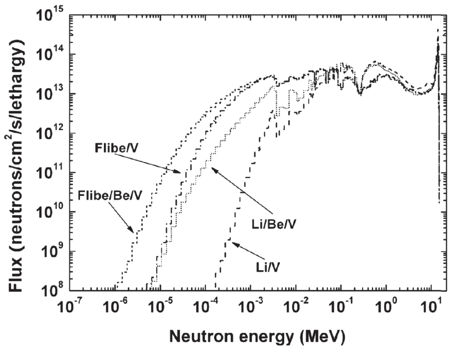

Fig. 2. Impact of additional solid beryllium neutron multiplier on neutron spectra in Li and Flibe cooled blankets.

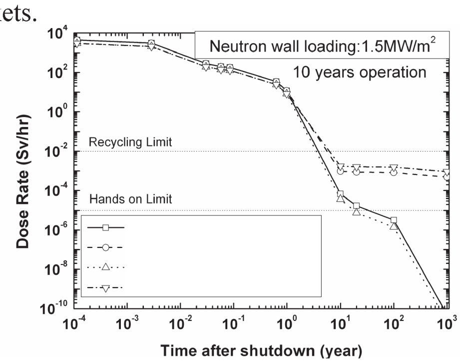

Fig. 3. Calculated radioactivities of V-alloy structural material and Er_2O_3 electrical insulating coating in Li cooled blanket systems with and without beryllium multiplier.